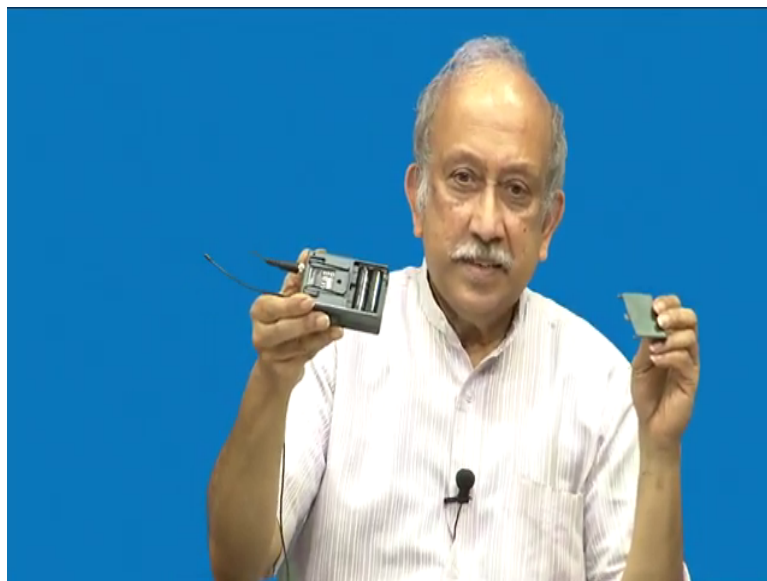


Electronics Equipment Integration and Prototype Building
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Lecture - 22
Introduction to sizing and fits

Hello, I am continuing where I had come so far in my earlier presentation or lecture. One of the first thing is saying from a simple two dimensional flat representation or earlier engineering drawings, we have now progressed towards 3D. The advantage of 3D being that it is easy for us to conceive something in a product like this no.

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We can conceive the product very well and try to manufacture it and using the same drawings which we have made, it is possible to now go ahead and produce the parts in large numbers.

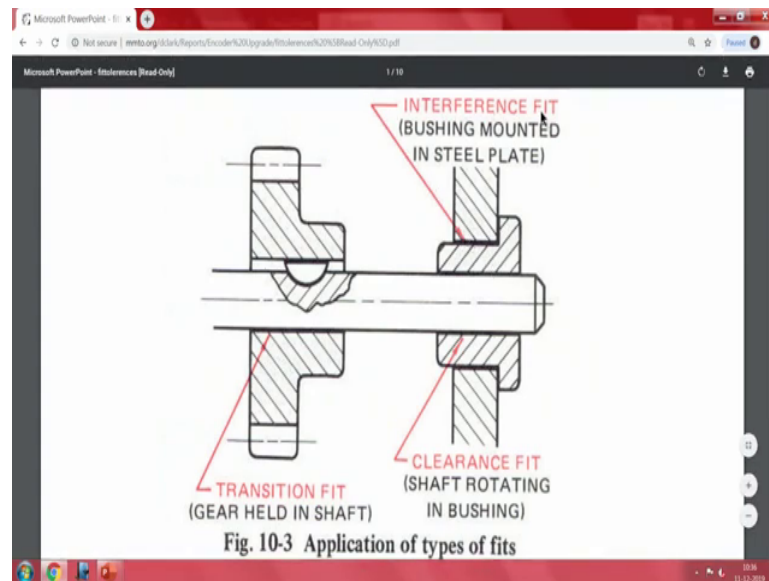
And, at this point we will end up with something which is, what you call developed very well and everybody understands about it. One of them is making things or mass production.

You have two ends two extreme options: one option is if there in reasonably large numbers and strength and such things are not that important and you can tolerate certain changes in thickness, you can go for plastic injection modeling. Allow me rather at this minute no, not to think about saying yes they can be made in so on and so on like that. One variation of this if you want strength is to use injection molding or die casting in a metallic devices.

So, earlier automobile things and all are typically non-ferrous die casted, die cast materials. And, in the case of this, this is a simple I will say inexpensive plastic injection molded part. The problem comes is normal times there is no issue at all in dealing with this thing, but kindly remember that this phase which is a cover. Lot of retailing has gone into it and this of course, the professional phase there is what you call wireless thing is a professional phase, hence lot of detailing and careful amount of things have been done and the tooling for this and the material for this are costly and it is constantly being improved.

In this case the enclosure is one part of it then the electronics inside and then the r f and how it come to the works and all is another type. And, if you come to toys there are very inexpensive toys where things are made with really low cost plastics. Now, one thing you will notice is this has been made in two different settings, but miraculously these things match. How do they match? This is where this whole lecture is about general type of fits and tolerances.

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Kindly look at my monitor one of the things you will notice is this has been derived from actual practice. So, this in a comprehensive way; this has been given all three fits are shown here. If you remember, I mentioned this about how to fit a bearing into a housing. So, this is the actually the starting point. If you notice here there is something has been done here to make sure that any bush usually, it will be a bond bush otherwise called gunmetal; its a made out of a one type of bronze material. Traditionally, this was done earlier and this itself is directly a bush which is used for various bearing type of applications.

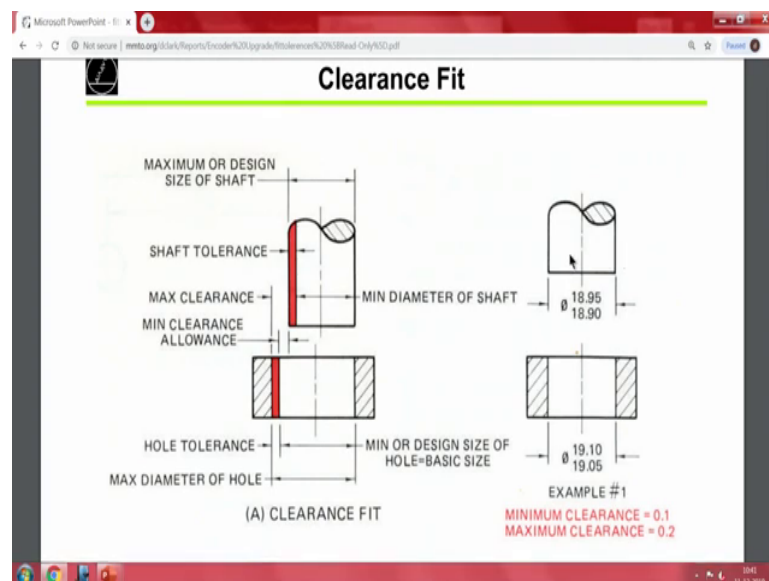
So in fact, you have bearing material separately the processing, then the metallurgy itself is slightly different. It is a softer material and it runs well and then it there is something about the tribology of it saying, how it takes oil and all that. So, you will see the outer part of it is called an interference fit. So, you push something and then you almost force it into that slot.

And, the other side we have here a clearance fit. A clearance fit is actually something, which is a rotating inside. Seen this, there is a beautiful option for it to rotate.

We are not going to put a separate ball bearing or anything here no there is no necessity of a ball bearing here. What is done is? You make a sufficient amount of a clearance here. So, that is what the word clearance is and the other extreme is a transition fit; meaning, sometimes it may lock sometimes it may not lock and we add an extra another item for it to hold it in place.

So, all these types are possible and depending on this thing in this particular thing is a key and there is a key way and then how we lock it inside is very very critical. Now, if I come down, this is what I was trying to talk to you yesterday.

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So, you will notice here that the whole itself can have a range of what you call permitted dimensions which come out based on the type of machining you use. Normally, if the machine is kept under one particular setting and the tools and all are good and the material is good and closely monitored, this follows a very average normal yield. It may be I have I am not talking about the statistical think about whether it is a bell curve, it is a normalized curve or anything, but it does follow certain things what you call certain yield which you can get from the machine.

Similarly, we have a shaft which it goes inside like this. So, you will end up with a very peculiar things saying this is the tolerance that has been given, this tolerance is represented here over 5 millimeters. And, similarly there is a tolerance which is given here whole tolerances that is also again and O 5 gap has given here, now when you actually try to assemble any what you call the shaft to any of the hole. So, something starting here you understand something starting here to this thing will be possible.

So, depending on the process, what has being adopted in the production shaft and depending on how you have select these things and put it together somebody has to have a good working knowledge of these things. Earlier it was easy, easy meaning; somebody will present it like this in a indication like this. So, this is where the what do you call things what I talked to you about saying there are norms that are there about the way you mentioned the what you call lines.

The way you mentioned this sectioning, the way you mention your tolerances, the way you mention the allowance that is there and so on like this have been adopted separately depending on how things have been progressed earlier. In manual craft usually things are assembled together and a little bit of running in is given.

So, it does not matter, if you are trying to make a grinding stone at home with a what you call an opening and then you have a that grinding stone inside it will behave one way and things like a puzzle and mortar the things are very very huge, there is no issue at all. But the moment

we have come in to the industrial revolution and you have to end up with the large number of interchangeable parts this business of clearance and tolerances has become very very real.

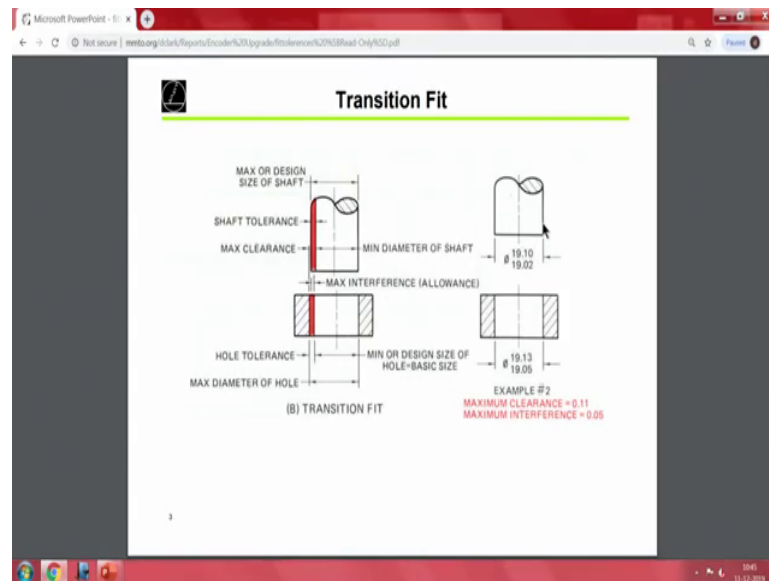
Now, the something which is very related to this is you cannot arbitrarily give anything you want here. Because, when it is produced in the machine shop, somebody has to set the machine and somebody has to inspect the parts saying which is acceptable, which is not acceptable. This is where to make a little a things little more inexpensive the concept of designating a batch came saying in fact, you can have all these things you know saying something which is on the lower and something which is nominal something which is higher and call it type A B C D.

Where the fit is very very critical as in the case of a cylinder and a piston or in the case of a cylinder liner, the whole thing is stamped on it after the measurement is done they stamped the designation on it saying this comes under the class A, meaning this follows this and so on. But then normally, earlier it was easy just had to make a drawing probably dimension it and write what you think was a reasonable amount of thing directly.

But now, once this CAD, the way of designation came about and especially both in the case of simple two dimensional or drafting representation versus actual 3D assembly representation, all this is to be carried out with due care. You cannot independently change anything you cannot change what is written there.

If you change it leads to a lot of problems. This is where the full fledged solid modulars with assembly and with various other checks have developed all these things inside automatically you can mention the class of fit to that is required. Now, go to the let me to the transition fit.

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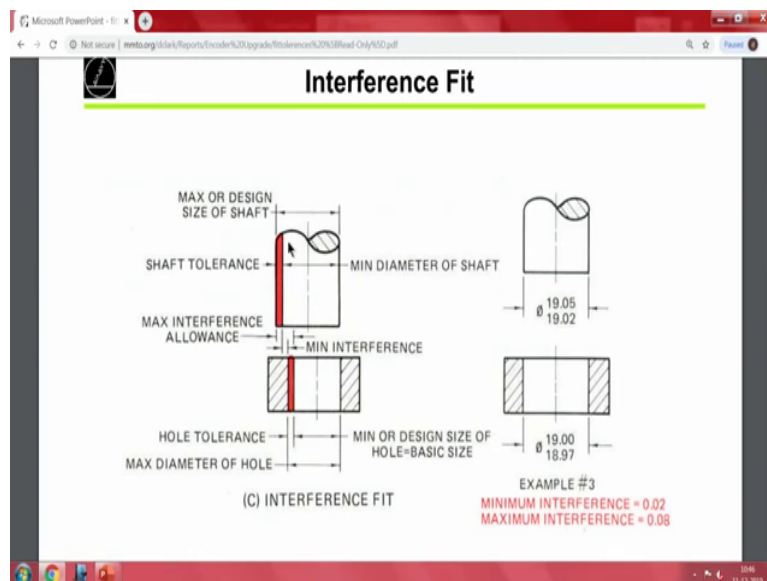
If you see here compared to the other one, you will notice here that both possibilities are there it is. If you take the shaft switches on the maximum diameter and then you take a this hole which is of the minimum diameter under some conditions an interference can occur. Now, it is for you to decide how to deal with it and so on. Right now, I will not talk about it I am just talking to you only about such a thing is called a transmission fit.

So, if you go here and the way things are made, we just we tend to give a some designation there and this is where things have changed a little over the years. It is not correct for you to arbitrarily give what you think is a reasonable what you call way of mentioning these things. The problem being to carry out this both the operation to carry out the inspection and trying to make the assembly this will become very uneconomical for you, if you keep on narrowing

these allowances and the tolerances; if you keep narrow while it can in principle you can make it a 0 0 0 or something it will be very very expensive to make such a thing.

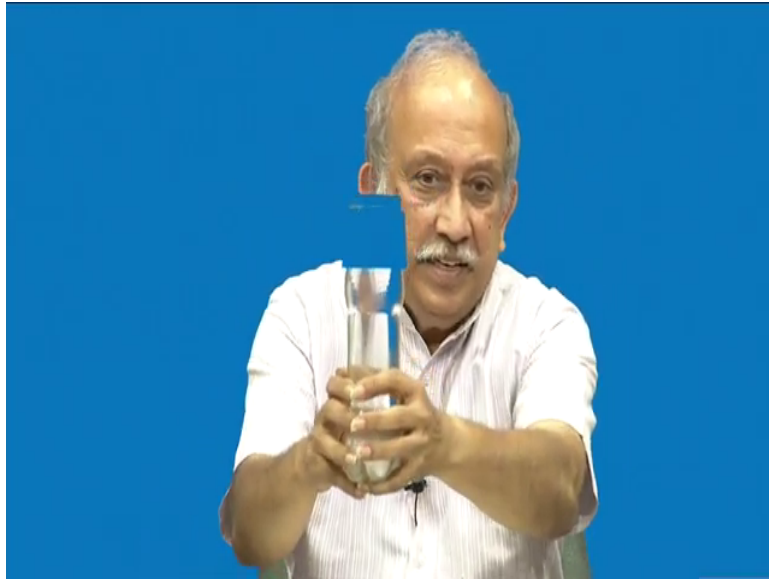
So, depending on the type of running and the type of thing, we need to make something. Now you come to genuine interference fit.

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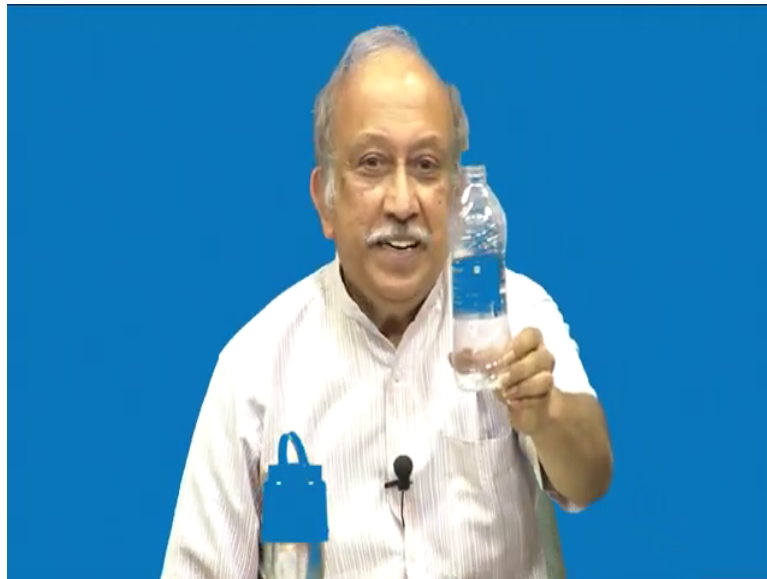
In the case of the interference fit under all conditions, under all conditions; there must be completely joint together and a lock itself only. This is called a pure interference fit. So, when if you remember the first example; there was a bearing slew fitted into a plate there under all conditions it should maintain itself well. Here, various types of things are there. So, have a look at this nice interesting thing I have.

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Sir, can you please show this? Say this oh it has got merged in it. So, maybe I should put it here very nice and interesting thing. Do not worry too much about the design. This has been made by a company and given as a nice go away compliment. I am trying to take a sip, good water with or without sprit tastes good.

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Now, if I see this, this is made by another company. They are probably competitors they have ensured that this will not fit this and they have patented the thing this thread and all they have patented. You have got my point, from purely from commercial point of view they have made a design by which it will not fit under all conditions you understand and naturally absolutely no problem even by mistake if I do it will not come which will make me come to a very very interesting aspect of this fabrication of this.

You will notice that this one is made by a what is called blow molding. Several of your toys, several of your things in your house, there is a particular die in which something is inserted and it blows and variations here are very very high understand no. The amount of things what you have to get is variations are very very high.

Further is the tremendous amount of design involved in it same, I am not sure whether its a previous year polypropylene bottle, same polypropylene bottle when it is used for holding water under normal pressure the thicknesses and things are different. And, when you would like to put carbonated or soda or many of our colas and all that this thickness is are different and cap is made by very traditional injection molding.

You see here this cap also has an injection molded cap, that is an injection molded cap. Now, how do you ensure that on all conditions any bottle will fit any cap that is there and then given the small cavy that I said this whole thing is made by blow molding and hence dimensions are not very stable. The issue is that is only part of the story, the part of the story is that though this part of it is blow molded; however, the former that is required for this one is injection molded.

If you see carefully, probably we will notice a flash and then you know how the thing is opened and all, how it is taken from the mold. And, then you will notice that this two that perfect amount of fit has been ensured and usually this thread formational will say is very very special and then we have something here and whole thing sits perfectly. Seen that because, here the tolerances in the injection molding are very good, here this has slightly softer materials. So, it can actually take little pressure and you know expand and fit the thing this remaining part is different.

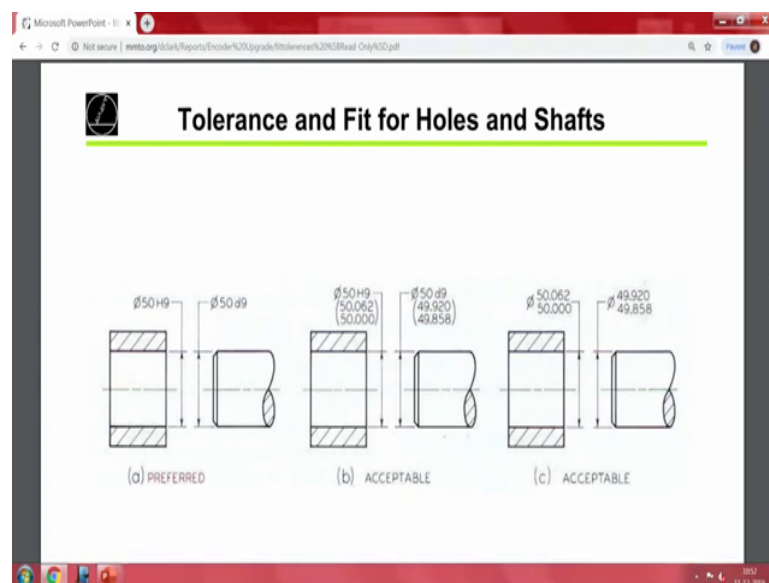
From here onwards actually it is a former that has made it looks like a longer tube like thing a little like an injection syringe then it is kept inside the what you call the injection mold and then some gasses in let into this. This is warmed up and it takes the shape afterwards and various ways are there, how to take it out and all if you are curious, you can just look it up, but what I would like to say is that a very routine ordinary thing on the among your collection, this needs lot of patients in designing and not just designing.

Now when we come to this if you see the way we show it on the on drawings this is very very clear. So, earlier I thought life is easy all we have to do is we go to the fabrication shop, we will go to the supplier and ask him what do you think is the best thing. So, I just erase you

know I have something called a modification or a change node here. I say this diameter 19 millimeters, the tolerances have been changed, but the moment this cad system came it is inconvenient to just go and rub out the dimensions and change it.

Instead you are expected to use a different thing. This is where it comes to advantage of having solid modular cads. If you take any of the things large number of them there, but in the parts where we live both the several of them specifically, solid edge, solid works both of them are I think from Siemens as well as a desalt and so many other people make this new solid modulars with what is called associative dimensioning by directional associated dimensioning meaning; if I change the dimension here or the tolerance here, the shape of this part and it changes automatically.

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Similarly, if I change the part this dimensions change automatically which helps in certain conditions we can look at it the very professional things also take care of various types of this toleranceing and fit for holes and shafts. You have seen something about this here which I was trying to tell you all the time probably it did not make much sense except people are actually in the field and this thing, if he had waited a little and this thing you will know what it is I was trying to talk to you about. This is called a designation of a fit.

So, a nominal dimension has been shown here saying it is a 50 millimeter nominal and from the nominal key letter designation, you will notice that capital H and 9 has been specified here and in the case of the, the shaft which goes inside a small lowercase letter and another number has been designated here. Combinations of this have been standardized with different types of materials, different types of operating conditions and so on.

Occasionally, people write down the actual values. This will help in case you are making a small number of numbers and you have a screw gauge or some other array profile projector with which you measure these dimensions. So, that you know where we stand.

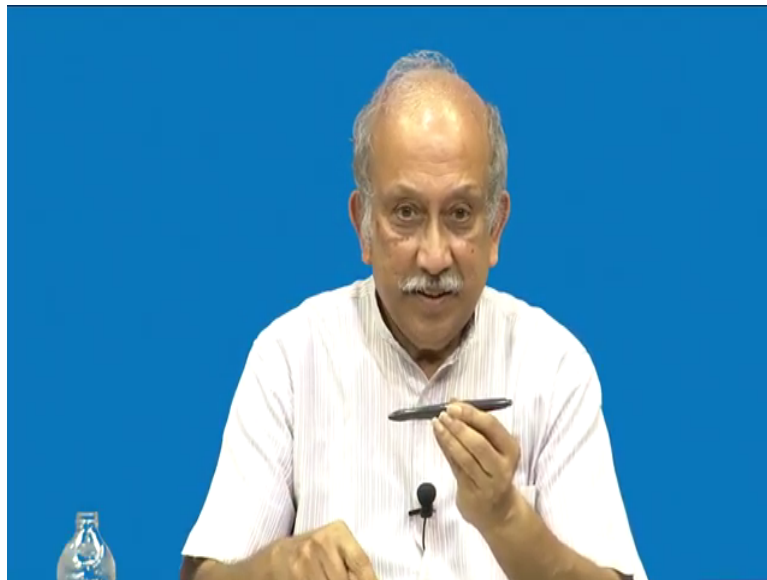
You understand no the both the dimensions the plus o 6 2 and the nominal this thing has been mentioned here in this case, in the case of shaft; while the nominal is 50 mm, what is designated here you have seen this 49.920 has been given here which is. People can read it and all that, but the thing is this corresponding this d 9 these things have to be perfect.

If somewhere in the previous drawing, if we change, we may end up with a little problem and imagine this part comes under in one a drawing, this part comes under in one drawing very difficult to manage this things every time. This is also acceptable instead of showing the nominal, the things have been explicitly written here saying this is it the thing, but the most preferred way is just to write the H9 and d 9 designation.

So, depending on your way of dealing and all that where each of these we have thread gauges, we have go, no go gauges and coming back to my example of it, if we have a thread gauge imagine this part of it has to be checked deliberately I have that thread gauge for this will

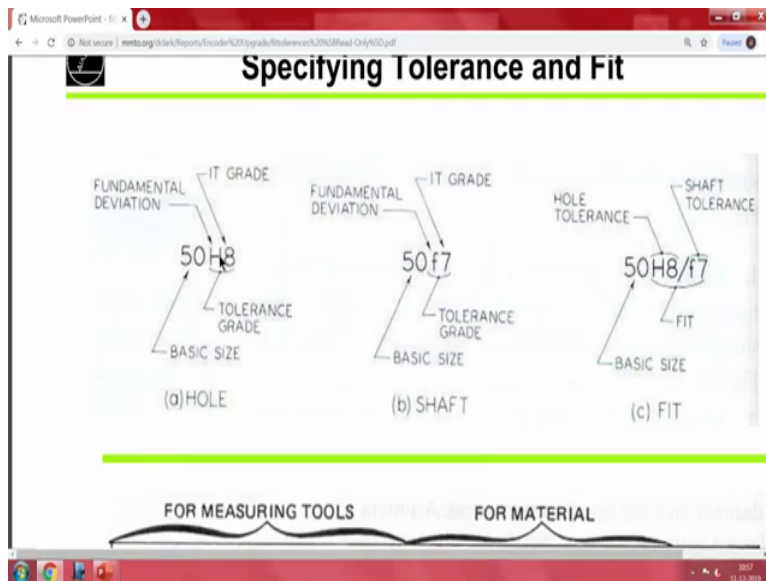
have something like this. On one end of the road, we will have a little larger thing saying it should not go inside if it goes inside; that means, this is larger the other end of it there will be a little smaller saying it must go inside.

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So, that will a imagine I will try to get a picture of it, imagine large hexagonal holder and one side you have a thread which follows whatever is shown here, another side and another thread which follows the other designation. I can just quickly put it; take random sampling acceptable quality level. If I get a bin of say 10000 parts I randomly select one try it here and pass all of them that is statistical. In statistical it has been what you call designated saying which should be a quality level.

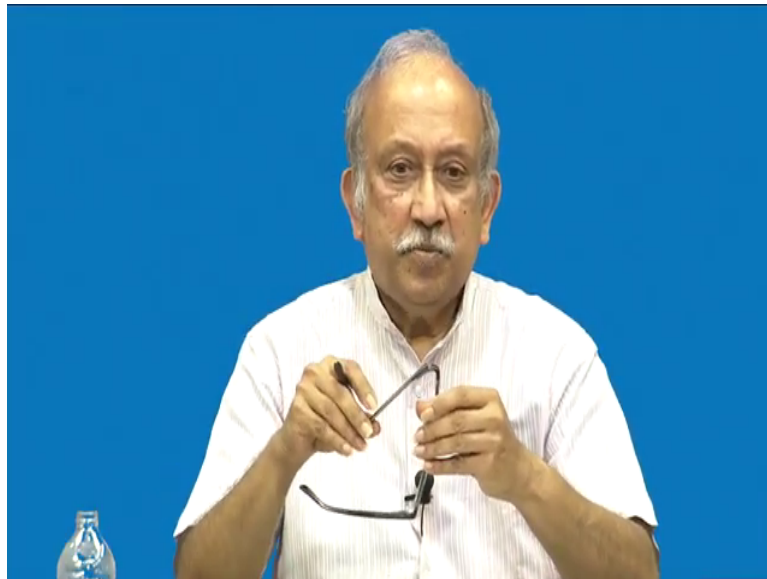
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Further if I go down now, you see here. At the extreme on the what you call the hole basic size has been maintained what you call, has been mentioned here and the tolerance grade including a letter designation and including a type of what is the type of fit that we require is mentioned here. H and all comes to things which are on one direction. Similarly, in the case of the hole, a smaller letter and then a different designation has been given and which I was trying to tell you is generally this combination of this saying H 8 f 7 on 50 is the wanted fit.

Now, we now come in to an important thing will the 50 be the same in case, I am sorry, will H 8 f 7 be the same incase it is a fine screw. Extreme fine screws probably what you like to find in a thing like your spectacle frames or you might find in your pen or you may find in your automobiles you understand no.

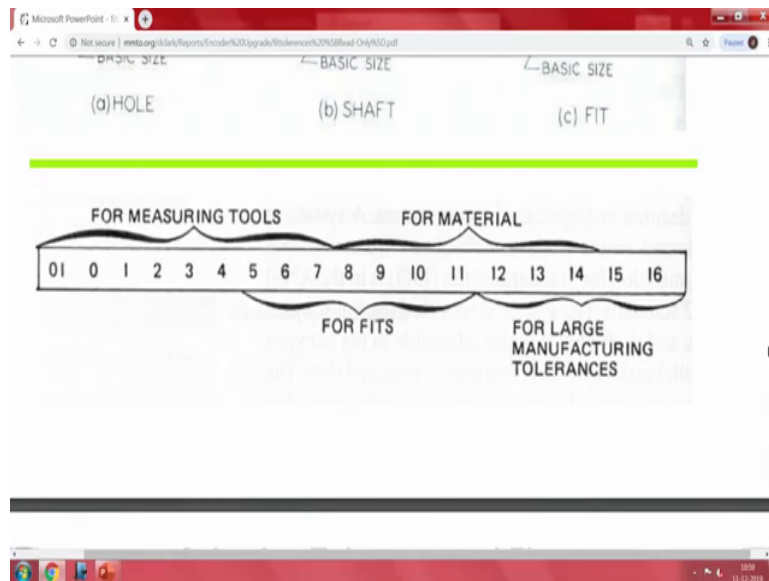
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This is extremely small and in fact, the diameter of this maybe is some 1.2 millimeters or 0.81 1.2 millimeters, is this the same for it? Yes, because they IT grade depends exclusively on the basic diameter up to say 0.1 mm to 0.4 mm it is one range and as it comes to 1 mm then from a say every 1 mm after that, later on depending on the type of trade depending on the type of material and so on these tolerances are cataloged and available in a book.

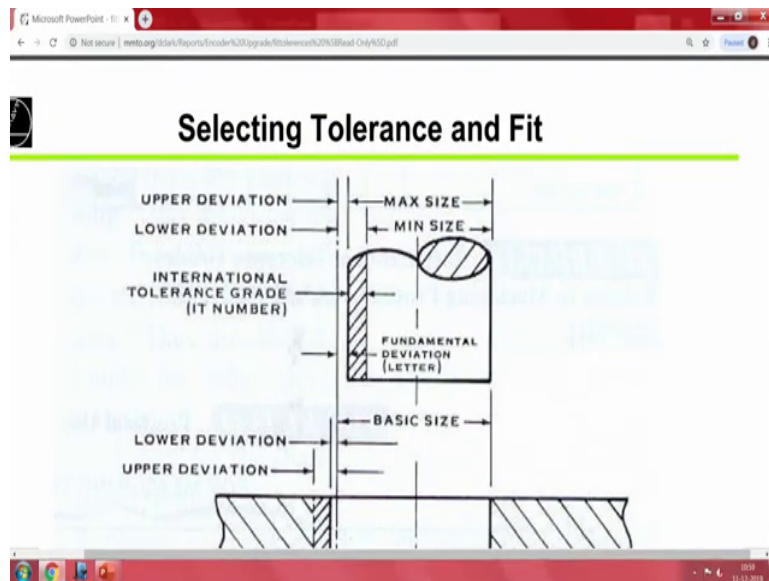
In fact, if you open the thing we have a huge table which shows the type of tolerances which are specified and large manufacture for measuring tools and then for materials for fits and all that no.

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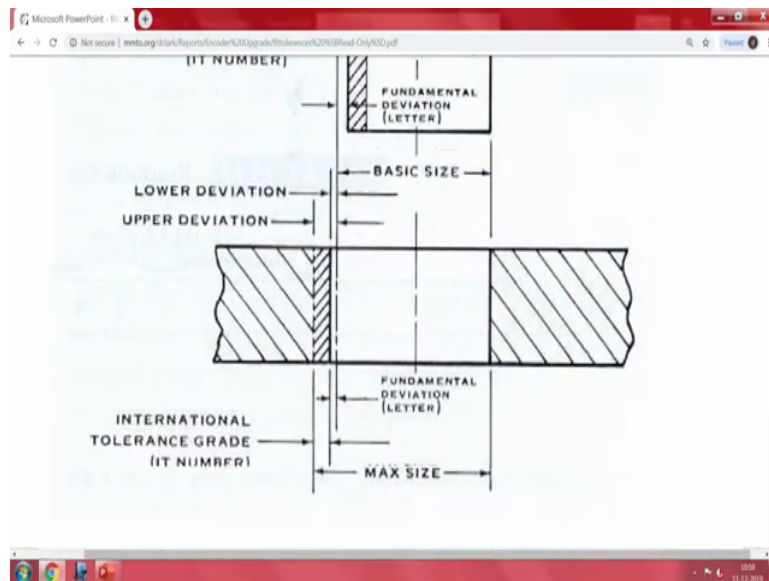


So, many of them have been specified. You understand know? Not easy it is tough, tough.

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Here comes the, how do you select a particular tolerance and fit? It comes to this chart which I was talking to what it is a huge chart.

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Tolerance Grade Chart

Basic sizes		Tolerance grades ^a																
Up to and including	IT01	IT0	IT1	IT2	IT3	IT4	IT5	IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14	IT15	IT16
3	0.0003	0.0005	0.0008	0.0012	0.002	0.003	0.004	0.006	0.010	0.014	0.025	0.040	0.060	0.100	0.140	0.250	0.400	0.600
6	0.0004	0.0006	0.001	0.0015	0.0025	0.004	0.005	0.008	0.012	0.018	0.030	0.048	0.075	0.120	0.180	0.300	0.480	0.750
10	0.0004	0.0006	0.001	0.0015	0.0025	0.004	0.006	0.009	0.015	0.022	0.036	0.058	0.090	0.150	0.220	0.360	0.580	0.900
18	0.0005	0.0008	0.0012	0.002	0.003	0.005	0.008	0.011	0.018	0.027	0.043	0.070	0.110	0.180	0.270	0.430	0.700	1.100
30	0.0006	0.001	0.0015	0.0025	0.004	0.006	0.009	0.013	0.021	0.033	0.052	0.084	0.130	0.210	0.330	0.520	0.840	1.300
50	0.0006	0.001	0.0015	0.0025	0.004	0.007	0.011	0.016	0.025	0.039	0.062	0.100	0.160	0.250	0.390	0.620	1.000	1.600
80	0.0008	0.0012	0.002	0.003	0.005	0.008	0.013	0.019	0.030	0.046	0.074	0.120	0.190	0.300	0.460	0.740	1.200	1.900
120	0.001	0.0015	0.0025	0.004	0.006	0.010	0.015	0.022	0.035	0.054	0.087	0.140	0.220	0.350	0.540	0.870	1.400	2.200
180	0.0012	0.002	0.0035	0.005	0.008	0.012	0.018	0.025	0.040	0.063	0.100	0.160	0.250	0.400	0.630	1.000	1.600	2.500
250	0.002	0.003	0.0045	0.007	0.010	0.014	0.020	0.029	0.046	0.072	0.115	0.185	0.290	0.460	0.730	1.150	1.850	2.900
315	0.0025	0.004	0.006	0.008	0.012	0.016	0.023	0.032	0.052	0.081	0.130	0.210	0.320	0.520	0.810	1.300	2.100	3.200
400	0.003	0.005	0.007	0.009	0.013	0.018	0.025	0.036	0.057	0.089	0.140	0.230	0.360	0.570	0.890	1.400	2.300	3.600
500	0.004	0.006	0.008	0.010	0.015	0.020	0.027	0.040	0.063	0.097	0.155	0.250	0.400	0.630	0.970	1.550	2.500	4.000
630	0.0045	0.006	0.009	0.011	0.016	0.022	0.030	0.044	0.070	0.110	0.175	0.280	0.440	0.700	1.100	1.750	2.800	4.400
800	0.005	0.007	0.010	0.013	0.018	0.025	0.035	0.050	0.080	0.125	0.200	0.320	0.500	0.800	1.250	2.000	3.200	5.000
1000	0.0055	0.008	0.011	0.015	0.021	0.029	0.040	0.056	0.090	0.140	0.230	0.360	0.560	0.900	1.400	2.300	3.600	5.600

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So, not easy, is it not? As you go to the left things are extremely expensive, very very expensive and then it goes to the right things are little inexpensive, understand. Imagine, you would like to make a something which you push into a wall followed no something which you push in to a wall if you give a very tight tolerance it is pointless very very expensive. Instead, if you give it toward the right it is easy that is the most of the dowels most of the that plastic or wooden things which you push into a wall will be they all towards the other extreme.

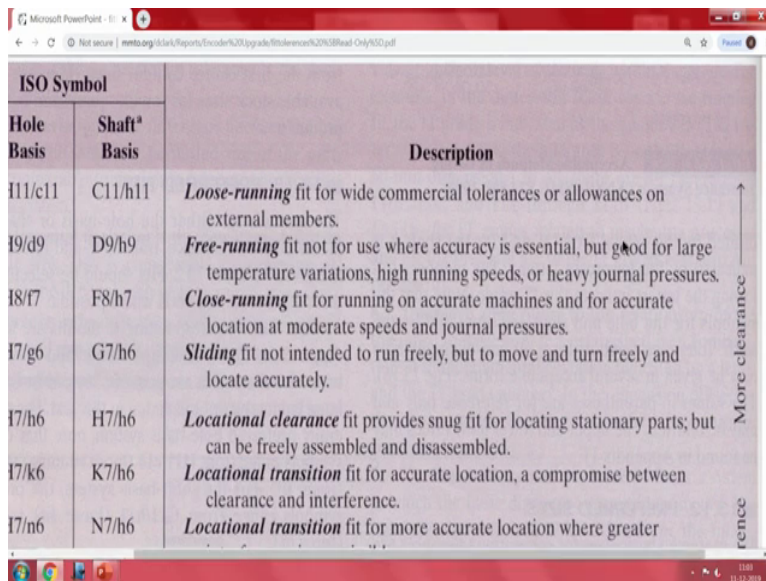
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ISO	IT01	IT02	IT03	IT04	IT05	IT06	IT07	IT08	IT09	IT10	IT11	IT12	IT13	IT14	IT15	IT16	IT17	IT18	IT19	IT20	IT21	IT22	IT23	IT24	IT25	IT26	IT27	IT28	IT29	IT30	IT31	IT32	IT33	IT34	IT35	IT36	IT37	IT38	IT39	IT40	IT41	IT42	IT43	IT44	IT45	IT46	IT47	IT48	IT49	IT50	IT51	IT52	IT53	IT54	IT55	IT56	IT57	IT58	IT59	IT60	IT61	IT62	IT63	IT64	IT65	IT66	IT67	IT68	IT69	IT70	IT71	IT72	IT73	IT74	IT75	IT76	IT77	IT78	IT79	IT80	IT81	IT82	IT83	IT84	IT85	IT86	IT87	IT88	IT89	IT90	IT91	IT92	IT93	IT94	IT95	IT96	IT97	IT98	IT99	IT100	IT101	IT102	IT103	IT104	IT105	IT106	IT107	IT108	IT109	IT110	IT111	IT112	IT113	IT114	IT115	IT116	IT117	IT118	IT119	IT120	IT121	IT122	IT123	IT124	IT125	IT126	IT127	IT128	IT129	IT130	IT131	IT132	IT133	IT134	IT135	IT136	IT137	IT138	IT139	IT140	IT141	IT142	IT143	IT144	IT145	IT146	IT147	IT148	IT149	IT150	IT151	IT152	IT153	IT154	IT155	IT156	IT157	IT158	IT159	IT160	IT161	IT162	IT163	IT164	IT165	IT166	IT167	IT168	IT169	IT170	IT171	IT172	IT173	IT174	IT175	IT176	IT177	IT178	IT179	IT180	IT181	IT182	IT183	IT184	IT185	IT186	IT187	IT188	IT189	IT190	IT191	IT192	IT193	IT194	IT195	IT196	IT197	IT198	IT199	IT200	IT201	IT202	IT203	IT204	IT205	IT206	IT207	IT208	IT209	IT210	IT211	IT212	IT213	IT214	IT215	IT216	IT217	IT218	IT219	IT220	IT221	IT222	IT223	IT224	IT225	IT226	IT227	IT228	IT229	IT230	IT231	IT232	IT233	IT234	IT235	IT236	IT237	IT238	IT239	IT240	IT241	IT242	IT243	IT244	IT245	IT246	IT247	IT248	IT249	IT250	IT251	IT252	IT253	IT254	IT255	IT256	IT257	IT258	IT259	IT260	IT261	IT262	IT263	IT264	IT265	IT266	IT267	IT268	IT269	IT270	IT271	IT272	IT273	IT274	IT275	IT276	IT277	IT278	IT279	IT280	IT281	IT282	IT283	IT284	IT285	IT286	IT287	IT288	IT289	IT290	IT291	IT292	IT293	IT294	IT295	IT296	IT297	IT298	IT299	IT300	IT301	IT302	IT303	IT304	IT305	IT306	IT307	IT308	IT309	IT310	IT311	IT312	IT313	IT314	IT315	IT316	IT317	IT318	IT319	IT320	IT321	IT322	IT323	IT324	IT325	IT326	IT327	IT328	IT329	IT330	IT331	IT332	IT333	IT334	IT335	IT336	IT337	IT338	IT339	IT340	IT341	IT342	IT343	IT344	IT345	IT346	IT347	IT348	IT349	IT350	IT351	IT352	IT353	IT354	IT355	IT356	IT357	IT358	IT359	IT360	IT361	IT362	IT363	IT364	IT365	IT366	IT367	IT368	IT369	IT370	IT371	IT372	IT373	IT374	IT375	IT376	IT377	IT378	IT379	IT380	IT381	IT382	IT383	IT384	IT385	IT386	IT387	IT388	IT389	IT390	IT391	IT392	IT393	IT394	IT395	IT396	IT397	IT398	IT399	IT400	IT401	IT402	IT403	IT404	IT405	IT406	IT407	IT408	IT409	IT410	IT411	IT412	IT413	IT414	IT415	IT416	IT417	IT418	IT419	IT420	IT421	IT422	IT423	IT424	IT425	IT426	IT427	IT428	IT429	IT430	IT431	IT432	IT433	IT434	IT435	IT436	IT437	IT438	IT439	IT440	IT441	IT442	IT443	IT444	IT445	IT446	IT447	IT448	IT449	IT450	IT451	IT452	IT453	IT454	IT455	IT456	IT457	IT458	IT459	IT460	IT461	IT462	IT463	IT464	IT465	IT466	IT467	IT468	IT469	IT470	IT471	IT472	IT473	IT474	IT475	IT476	IT477	IT478	IT479	IT480	IT481	IT482	IT483	IT484	IT485	IT486	IT487	IT488	IT489	IT490	IT491	IT492	IT493	IT494	IT495	IT496	IT497	IT498	IT499	IT500	IT501	IT502	IT503	IT504	IT505	IT506	IT507	IT508	IT509	IT510	IT511	IT512	IT513	IT514	IT515	IT516	IT517	IT518	IT519	IT520	IT521	IT522	IT523	IT524	IT525	IT526	IT527	IT528	IT529	IT530	IT531	IT532	IT533	IT534	IT535	IT536	IT537	IT538	IT539	IT540	IT541	IT542	IT543	IT544	IT545	IT546	IT547	IT548	IT549	IT550	IT551	IT552	IT553	IT554	IT555	IT556	IT557	IT558	IT559	IT560	IT561	IT562	IT563	IT564	IT565	IT566	IT567	IT568	IT569	IT570	IT571	IT572	IT573	IT574	IT575	IT576	IT577	IT578	IT579	IT580	IT581	IT582	IT583	IT584	IT585	IT586	IT587	IT588	IT589	IT590	IT591	IT592	IT593	IT594	IT595	IT596	IT597	IT598	IT599	IT600	IT601	IT602	IT603	IT604	IT605	IT606	IT607	IT608	IT609	IT610	IT611	IT612	IT613	IT614	IT615	IT616	IT617	IT618	IT619	IT620	IT621	IT622	IT623	IT624	IT625	IT626	IT627	IT628	IT629	IT630	IT631	IT632	IT633	IT634	IT635	IT636	IT637	IT638	IT639	IT640	IT641	IT642	IT643	IT644	IT645	IT646	IT647	IT648	IT649	IT650	IT651	IT652	IT653	IT654	IT655	IT656	IT657	IT658	IT659	IT660	IT661	IT662	IT663	IT664	IT665	IT666	IT667	IT668	IT669	IT670	IT671	IT672	IT673	IT674	IT675	IT676	IT677	IT678	IT679	IT680	IT681	IT682	IT683	IT684	IT685	IT686	IT687	IT688	IT689	IT690	IT691	IT692	IT693	IT694	IT695	IT696	IT697	IT698	IT699	IT700	IT701	IT702	IT703	IT704	IT705	IT706	IT707	IT708	IT709	IT710	IT711	IT712	IT713	IT714	IT715	IT716	IT717	IT718	IT719	IT720	IT721	IT722	IT723	IT724	IT725	IT726	IT727	IT728	IT729	IT730	IT731	IT732	IT733	IT734	IT735	IT736	IT737	IT738	IT739	IT740	IT741	IT742	IT743	IT744	IT745	IT746	IT747	IT748	IT749	IT750	IT751	IT752	IT753	IT754	IT755	IT756	IT757	IT758	IT759	IT760	IT761	IT762	IT763	IT764	IT765	IT766	IT767	IT768	IT769	IT770	IT771	IT772	IT773	IT774	IT775	IT776	IT777	IT778	IT779	IT780	IT781	IT782	IT783	IT784	IT785	IT786	IT787	IT788	IT789	IT790	IT791	IT792	IT793	IT794	IT795	IT796	IT797	IT798	IT799	IT800	IT801	IT802	IT803	IT804	IT805	IT806	IT807	IT808	IT809	IT810	IT811	IT812	IT813	IT814	IT815	IT816	IT817	IT818	IT819	IT820	IT821	IT822	IT823	IT824	IT825	IT826	IT827	IT828	IT829	IT830	IT831	IT832	IT833	IT834	IT835	IT836	IT837	IT838	IT839	IT840	IT841	IT842	IT843	IT844	IT845	IT846	IT847	IT848	IT849	IT850	IT851	IT852	IT853	IT854	IT855	IT856	IT857	IT858	IT859	IT860	IT861	IT862	IT863	IT864	IT865	IT866	IT867	IT868	IT869	IT870	IT871	IT872	IT873	IT874	IT875	IT876	IT877	IT878	IT879	IT880	IT881	IT882	IT883	IT884	IT885	IT886	IT887	IT888	IT889	IT890	IT891	IT892	IT893	IT894	IT895	IT896	IT897	IT898	IT899	IT900	IT901	IT902	IT903	IT904	IT905	IT906	IT907	IT908	IT909	IT910	IT911	IT912	IT913	IT914	IT915	IT916	IT917	IT918	IT919	IT920	IT921	IT922	IT923	IT924	IT925	IT926	IT927	IT928	IT929	IT930	IT931	IT932	IT933	IT934	IT935	IT936	IT937	IT938	IT939	IT940	IT941	IT942	IT943	IT944	IT945	IT946	IT947	IT948	IT949	IT950	IT951	IT952	IT953	IT954	IT955	IT956	IT957	IT958	IT959	IT960	IT961	IT962	IT963	IT964	IT965	IT966	IT967	IT968	IT969	IT970	IT971	IT972	IT973	IT974	IT975	IT976	IT977	IT978	IT979	IT980	IT981	IT982	IT983	IT984	IT985	IT986	IT987	IT988	IT989	IT990	IT991	IT992	IT993	IT994	IT995	IT996	IT997	IT998	IT999	IT1000	IT1001	IT1002	IT1003	IT1004	IT1005	IT1006	IT1007	IT1008	IT1009	IT1010	IT1011	IT1012	IT1013	IT1014	IT1015	IT1016	IT1017	IT1018	IT1019	IT1020	IT1021	IT1022	IT1023	IT1024	IT1025	IT1026	IT1027	IT1028	IT1029	IT1030	IT1031	IT1032	IT1033	IT1034	IT1035	IT1036	IT1037	IT1038	IT1039	IT1040	IT1041	IT1042	IT1043	IT1044	IT1045	IT1046	IT1047	IT1048	IT1049	IT1050	IT1051	IT1052	IT1053	IT1054	IT1055	IT1056	IT1057	IT1058	IT1059	IT1060	IT1061	IT1062	IT1063	IT1064	IT1065	IT1066	IT1067	IT1068	IT1069	IT1070	IT1071	IT1072	IT1073	IT1074	IT1075	IT1076	IT1077	IT1078	IT1079	IT1080	IT1081	IT1082	IT1083	IT1084	IT1085	IT1086	IT1087	IT1088	IT1089	IT1090	IT1091	IT1092	IT1093	IT1094	IT1095	IT1096	IT1097	IT1098	IT1099	IT1100	IT1101	IT1102	IT1103	IT1104	IT1105	IT1106	IT1107	IT1108	IT1109	IT1110	IT1111	IT1112	IT1113	IT1114	IT1115	IT1116	IT1117	IT1118	IT1119	IT1120	IT1121	IT1122	IT1123	IT1124	IT1125	IT1126	IT1127	IT1128	IT1129	IT1130	IT1131	IT1132	IT1133	IT1134	IT1135	IT1136	IT1137	IT1138	IT1139	IT1140	IT1141	IT1142	IT1143	IT1144	IT1145	IT1146	IT1147	IT1148	IT1149	IT1150	IT1151	IT1152	IT1153	IT1154	IT1155	IT1156	IT1157	IT1158	IT1159	IT1160	IT1161	IT1162	IT1163	IT1164	IT1165	IT1166	IT1167	IT1168	IT1169	IT1170	IT1171	IT1172	IT1173	IT1174	IT1175	IT1176	IT1177	IT1178	IT1179	IT1180	IT1181	IT1182	IT1183	IT1184	IT1185	IT1186	IT1187	IT1188	IT1189	IT1190	IT1191	IT1192	IT1193	IT1194	IT1195	IT1196	IT1197	IT1198	IT1199	IT1200	IT1201	IT1202	IT1203	IT1204	IT1205	IT1206	IT1207	IT1208	IT1209	IT1210	IT1211	IT1212	IT1213	IT1214	IT1215	IT1216	IT1217	IT1218	IT1219	IT1220	IT1221	IT1222	IT1223	IT1224	IT1225	IT1226	IT1227	IT1228	IT1229	IT1230	IT1231	IT1232	IT1233	IT1234	IT1235	IT1236	IT1237	IT1238	IT1239	IT1240	IT1241	IT1242	IT1243	IT1244	IT1245	IT1246	IT1247	IT1248	IT1249	IT1250	IT1251	IT1252	IT1253	IT1254	IT1255	IT1256	IT1257	IT1258	IT1259	IT1260	IT1261	IT1262	IT1263	IT1264	IT1265	IT1266	IT1267	IT1268	IT1269	IT1270	IT1271	IT1272	IT1273	IT1274	IT1275	IT1276	IT1277	IT1278	IT1279	IT1280	IT1281	IT1282	IT1283	IT1284	IT1285	IT1286	IT1287	IT1288	IT1289	IT1290	IT1291	IT1292	IT1293	IT1294	IT1295	IT1296	IT1297	IT1298	IT1299	IT1300	IT1301	IT1302	IT1303	IT1304	IT1305	IT1306	IT1307	IT1308	IT1309	IT1310	IT1311	IT1312	IT1313	IT1314	IT1315	IT1316	IT1317	IT1318	IT1319	IT1320	IT1321	IT1322	IT1323	IT1324	IT1325	IT1326	IT1327	IT1328	IT1329	IT1330	IT1331	IT1332	IT1333	IT1334
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ISO Symbol		Description
Hole Basis	Shaft Basis	
H11/c11	C11/h11	Loose-running fit for wide commercial tolerances or allowances on external members.
H9/d9	D9/h9	Free-running fit not for use where accuracy is essential, but good for large temperature variations, high running speeds, or heavy journal pressures.
H8/f7	F8/h7	Close-running fit for running on accurate machines and for accurate location at moderate speeds and journal pressures.
H7/g6	G7/h6	Sliding fit not intended to run freely, but to move and turn freely and locate accurately.
H7/h6	H7/h6	Locational clearance fit provides snug fit for locating stationary parts; but can be freely assembled and disassembled.
H7/k6	K7/h6	Locational transition fit for accurate location, a compromise between clearance and interference.
H7/n6	N7/h6	Locational transition fit for more accurate location where greater

Come from left to the right, you keep reading it. You will know my voice may be a little irritating. So, you see hole basis, shaft basis and so on and so on. So, we have things like H 11 c 11, saying there is a loose running fit for wide commercial tolerance or allowance on external members; so, again, once again simple commercial.

Very easy to achieve does not cost too much money and if you are starting from the what you call I will I will leave you to read the bottom part towards the end of this. And locational or sliding fit yeah, there is a there is something which is quite important free running you are not for use where accuracy essential. But good for large temperature variations, high running speeds are heavy journal pressures

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Fit Type	Fit Designation	Description
Clearance	H9/d9	Free-running fit not for use where accuracy is essential, but good for large temperature variations, high running speeds, or heavy journal pressures.
	H8/h7	Close-running fit for running on accurate machines and for accurate location at moderate speeds and journal pressures.
	H7/g6	Sliding fit not intended to run freely, but to move and turn freely and locate accurately.
Transition Fits	H7/h6	Locational clearance fit provides snug fit for locating stationary parts; but can be freely assembled and disassembled.
	H7/k6	Locational transition fit for accurate location, a compromise between clearance and interference.
	H7/n6	Locational transition fit for more accurate location where greater interference is permissible.
Interference Fits	H7/p6	Locational interference fit for parts requiring rigidity and alignment with prime accuracy of location but without special bore pressure requirements.
	H7/s6	Medium drive fit for ordinary steel parts or shrink fits on light sections, the tightest fit usable with cast iron.
	H7/u6	Force fit suitable for parts which can be highly stressed or for shrink fits where the heavy pressing forces required are impractical.

Loosely this has been taken from one of the what do you call the general engineering descriptions, but all of these are based on actual practices. You understand no, actual practices on how to make things work. Then somebody has actually taken a bush, then they have found out they have run it on a typical if it is a large number they are run it on a automate called as switch automate or any of them depending on where you come from average ports and then we have any number of this small machines which quickly maintain all of these things on the other end we have accurate machines close running fit.

And, for accurate location at moderate speeds and journal pressures typically, you are sewing machine at home may have this type of a close running fit. You have seen not many bearings the way we know no not many roller or ball bearings a little bit there in that machines. What will require is actually there is a bush and then you can rotate it and usually there is a in case

there is a let us say this is a bush like this then there is a shaft which is moving inside and usually that whole thing moves inside, there is a small opening for you to lubricate it.

In that condition this is the best and original singer machines and all that. They still work a 100 years after they have been made and sold and then they work very very well without the least amount of any problems. They continue to work like this. That is because somebody has paid attention to two details one of it is the type of journal that you need it and the how easy to achieve it and the type of that sliding part inside this.

Now, you may come to know the things are it things are so loose, how can we make these things work there it is not every time things are made such that they are non-recoverable non-repairable or you know we can tolerate with the yield usually, what is called a second operation including a reamer is passed on to that.

If the shaft is made standard we will not touch the shaft too much because making it there is a problem; however, if there is an opening you can make what is called a proper reamer and adjust it to that. So, imagine you need to make a 3.8 mm hole. Probably it is made into 3.75 and you have a special reamer which exactly goes inside and turns and when you take it off nicely it sits there without any problem.

So, using this combination of, I would not call it rework using a combination of second operation and using a shaft, it is possible for you to achieve much much closer fits and things work for a very long time and a lot depends on the metallurgy status of lubrication and how things work. Otherwise you would not be having all that old type of vehicles, old type of sewing machines typewriters and anything you have in your house and if you are a romantic about an old thing, they were made in small numbers and usually closely inspected and expensive at that time.

But right now, even you can buy a very beautiful a combination programmable sewing machine does not cost too much. It is much much inexpensive compared to the old fab machines or compared to now the various other machines and similarly, when you are going to apparel work; they have machines which work at very high speeds and you do not have a

treadmill you do not have a hand instead you have a big motor and sometimes there is a pressurized case in which all the oil is recirculated its pumped inside.

Hence, things like if you take a tough material like jeans or if you take certain huge curtains made of thick materials they are just fed and in one shot like no it will be things it will be moving at great speed. The secret is what started as a almost you know handcrafted devices have now become automated and why I am mentioning it, I am not deviating I just wanted to tell you that all this is now possible for us to make instead of that manual drafting.

If you make a proper 3D model and if you mentioned this tolerances and relevance and if you also work closely with these various things, that are mentioned here. Medium drive for ordinary steel parts are shrink parts on light sections, tutus with usable with cast iron. You may have wondered how sleeves are fitted into a internal combustion engine, that whole outer casing is made of anything. Right now its aluminum, otherwise earlier it is to be variants of cast iron and steels and you have sleeve which have just to go inside.

So, what is done is the sleeve is kept a cooled oil and the casting is probably a little warmer than ambient. So, that it expands a little while this is closed and just by hand things are pushed. Once they are pushed by hand they just locked permanently. Once the temperature comes back to the normal and imagine that if you have a cylinder liner it is always hotter than the usual ambient they just after a little bit of running in it sits permanently, there is no other way of knocking it of some of them have a prohibition of pulling it out otherwise they probably machine it and put some other things.

And, coming back to this things like pistons and the what you call cylinders they come with grades printed on them saying depending on the type of liner you have depending on the type of reburying you do, you can select a different piston. And, even there you have piston rings which need to have these things may being a mechanical engineer the stress is a little more on this.

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Preferred Clearance Fit Tolerances

Basic Size	Loose Running			Free Running			Close Running			Sliding			Locational Clearance		
	Hole H11	Shaft s11	Fit	Hole H9	Shaft d9	Fit	Hole H8	f7	Fit	Hole H7	shaft g6	Fit	Hole H7	Shaft h6	Fit
1	Max 1.060	0.940	0.180	1.025	0.980	0.070	1.014	0.994	0.030	1.010	0.998	0.018	1.010	1.000	0.016
	Min 1.060	0.880	0.060	1.000	0.955	0.020	1.000	0.984	0.006	1.000	0.992	0.002	1.000	0.994	0.000
1.2	Max 1.260	1.140	0.180	1.225	1.180	0.070	1.214	1.194	0.030	1.210	1.198	0.018	1.210	1.200	0.016
	Min 1.200	1.080	0.060	1.200	1.155	0.020	1.200	1.184	0.036	1.200	1.192	0.002	1.200	1.194	0.000
1.6	Max 1.660	1.540	0.180	1.625	1.580	0.070	1.614	1.594	0.030	1.610	1.598	0.018	1.610	1.600	0.016
	Min 1.600	1.480	0.060	1.600	1.555	0.020	1.600	1.584	0.006	1.600	1.592	0.002	1.600	1.594	0.000
2	Max 2.060	1.940	0.180	2.025	1.980	0.070	2.014	1.994	0.030	2.010	1.998	0.018	2.010	2.000	0.016
	Min 2.000	1.880	0.060	2.000	1.955	0.020	2.000	1.984	0.006	2.000	1.992	0.002	2.000	1.994	0.000
2.5	Max 2.560	2.440	0.180	2.525	2.480	0.070	2.514	2.494	0.030	2.510	2.498	0.018	2.510	2.500	0.016
	Min 2.500	2.380	0.060	2.500	2.455	0.020	2.500	2.484	0.006	2.500	2.492	0.002	2.500	2.494	0.000
3	Max 3.060	2.940	0.180	3.025	2.980	0.070	3.014	2.994	0.030	3.010	2.998	0.018	3.010	3.000	0.016
	Min 3.000	2.880	0.060	3.000	2.955	0.020	3.000	2.984	0.006	3.000	2.992	0.002	3.000	2.994	0.000
4	Max 4.075	3.930	0.220	4.030	3.970	0.060	4.018	3.990	0.040	4.012	3.996	0.024	4.012	4.000	0.020
	Min 4.000	3.855	0.070	4.000	3.940	0.030	4.000	3.978	0.010	4.000	3.988	0.004	4.000	3.992	0.000
5	Max 5.075	4.930	0.220	5.030	4.970	0.060	5.018	4.990	0.040	5.012	4.996	0.024	5.012	5.000	0.020
	Min 5.000	4.855	0.070	5.000	4.940	0.030	5.000	4.978	0.010	5.000	4.988	0.004	5.000	4.992	0.000
6	Max 6.075	5.930	0.220	6.030	5.970	0.060	6.018	5.990	0.040	6.012	5.996	0.024	6.012	6.000	0.020
	Min 6.000	5.855	0.070	6.000	5.940	0.030	6.000	5.978	0.010	6.000	5.988	0.004	6.000	5.992	0.000

So, we have here a big clearance fit table and it shows under all conditions how things run and so on. Basic size at 1 millimeter and it goes on and on like this and then, we have all these things which are happily they work peacefully without the slightest, what you call a confession on the workshop premises.

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2	Max	2.060	1.940	0.180	2.025	1.980	0.070	2.014	1.994	0.030	2.010	1.998	0.018	2.010	2.000	0.016
	Min	2.000	1.880	0.060	2.000	1.955	0.020	2.000	1.984	0.006	2.000	1.992	0.002	2.000	1.994	0.000
2.5	Max	2.560	2.440	0.180	2.525	2.480	0.070	2.514	2.494	0.030	2.510	2.498	0.018	2.510	2.500	0.016
	Min	2.500	2.380	0.060	2.500	2.455	0.020	2.500	2.484	0.006	2.500	2.492	0.002	2.500	2.494	0.000
3	Max	3.060	2.940	0.180	3.025	2.980	0.070	3.014	2.994	0.030	3.010	2.998	0.018	3.010	3.000	0.016
	Min	3.000	2.880	0.060	3.000	2.955	0.020	3.000	2.984	0.006	3.000	2.992	0.002	3.000	2.994	0.000
4	Max	4.075	3.930	0.220	4.030	3.975	0.020	4.018	3.990	0.040	4.012	3.996	0.024	4.012	4.000	0.020
	Min	4.000	3.855	0.070	4.000	3.940	0.030	4.000	3.978	0.010	4.000	3.988	0.004	4.000	3.992	0.000
5	Max	5.075	4.930	0.220	5.030	4.975	0.070	5.018	4.990	0.040	5.012	4.996	0.024	5.012	5.000	0.020
	Min	5.000	4.855	0.070	5.000	4.940	0.030	5.000	4.978	0.010	5.000	4.988	0.004	5.000	4.992	0.000
6	Max	6.075	5.930	0.220	6.030	5.975	0.090	6.018	5.990	0.040	6.012	5.996	0.024	6.012	6.000	0.020
	Min	6.000	5.855	0.070	6.000	5.940	0.030	6.000	5.978	0.010	6.000	5.988	0.004	6.000	5.992	0.000
8	Max	8.090	7.920	0.260	8.036	7.960	0.112	8.022	7.987	0.050	8.015	7.995	0.029	8.015	8.000	0.024
	Min	8.000	7.830	0.080	8.000	7.924	0.040	8.000	7.972	0.010	8.000	7.986	0.005	8.000	7.991	0.000
10	Max	10.090	9.920	0.260	10.036	9.960	0.112	10.022	9.987	0.050	10.015	9.995	0.029	10.015	10.000	0.024
	Min	10.000	9.830	0.080	10.000	9.924	0.040	10.000	9.972	0.010	10.000	9.986	0.005	10.000	9.991	0.000
12	Max	12.110	11.905	0.315	12.043	11.995	0.136	12.027	11.984	0.061	12.018	11.994	0.035	12.018	12.000	0.029
	Min	12.000	11.795	0.095	12.000	11.907	0.050	12.000	11.966	0.016	12.000	11.983	0.006	12.000	11.989	0.000
16	Max	16.110	15.905	0.315	16.043	15.950	0.136	16.027	15.984	0.061	16.018	15.994	0.035	16.018	16.000	0.029
	Min	16.000	15.795	0.095	16.000	15.907	0.050	16.000	15.966	0.016	16.000	15.983	0.006	16.000	15.989	0.000
20	Max	20.130	19.890	0.370	20.052	19.935	0.169	20.035	19.980	0.074	20.021	19.993	0.041	20.021	20.000	0.034
	Min	20.000	19.760	0.110	20.000	19.883	0.065	20.000	19.959	0.020	20.000	19.960	0.007	20.000	19.987	0.000
25	Max	25.130	24.890	0.370	25.052	24.935	0.169	25.035	24.980	0.074	25.021	24.993	0.041	25.021	25.000	0.034
	Min	25.000	24.760	0.110	25.000	24.883	0.065	25.000	24.959	0.020	25.000	24.980	0.007	25.000	24.987	0.000
30	Max	30.130	29.890	0.370	30.052	29.935	0.169	30.035	29.980	0.074	30.021	29.993	0.041	30.021	30.000	0.034
	Min	30.000	29.760	0.110	30.000	29.883	0.065	30.000	29.959	0.020	30.000	29.980	0.007	30.000	29.987	0.000

10

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You can easily specifies these things in the drawing. And, now again one more time let me tell you in the new type of software where solid modeling is done, there is a provision for you to include all these things in that. So, you are seen that bush first drawing if you see if you remember I will take you back to the very very first drawing.

It is possible now you mention a proper type of fit here, you mention a proper type of allowance here or clearance fit and due to some optimization or something let us say you decide to change the shaft saying instead of a 6 millimeter shaft or I will put it the other way instead of a one-eighth inch shaft which is going to be three point something something which will change to a 3.2, because the quarter inch is 6.35. So, that the other shaft could be 3.175 and the new shaft we have is 3.2 millimeters which is slightly different or you may end up with the 3 millimeter shaft.

Now, you have the advantage of you know you can play with all these things and at one place if you change all of the other things will be taken care of it also involves that you mention what is the minimum material that is required for the bush. So, the full fledged assembly software, all these things are peacefully built into the software and I mean life goes on without the slightest thing life goes on peacefully.

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web.mit.edu/2.75/resources/random/Sheet%20metal%20Tolerance%202.pdf

GENERAL DIMENSIONAL TOLERANCES FOR SHEET METAL FORMED PARTS. (UNLESS OTHERWISE SPECIFIED)				
Dimension Range	Edge to edge, or hole to hole, (NO BEND AREA) FLAT Dimension A	Edge or hole to bend* Dimension B	Bend to bend* Dimension C	Angular Tolerances Dimension D
0.25" or less (6.35mm or less)	$\pm 0.005"$ (0.13mm)	$\pm 0.01"$ (0.25mm)	$\pm 0.01"$ (0.25mm)	± 2 degree
over 0.25" to 1" incl. (over 6.35mm to 25.4mm)	$\pm 0.006"$ (0.15mm)	$\pm 0.01"$ (0.25mm)	$\pm 0.015"$ (0.38mm)	
over 1" to 5" incl. (over 25.4mm to 127mm)	$\pm 0.007"$ (0.18mm)	$\pm 0.01"$ (0.25mm)	$\pm 0.015"$ (0.38mm)	
over 5" to 16" incl. (over 127mm to 406mm)	$\pm 0.008"$ (0.20mm)	$\pm 0.015"$ (0.38mm)	$\pm 0.02"$ (0.51mm)	
over 16" to 40" incl. (over 406mm to 1016mm)	$\pm 0.01"$ (0.25mm)	$\pm 0.02"$ (0.51mm)	$\pm 0.02"$ (0.51mm)	
over 40" to 96" incl. (over 1016mm to 2286mm)	$\pm 0.02"$ (0.5mm)	$\pm 0.025"$ (0.64mm)	$\pm 0.04"$ (1.27mm)	

* Tolerance will increase if more than one bend (such as Dimension E)

So, if I now go back to the most of our electronic enclosures end of it being made with sheet metal and sheet metal by definition somehow it just means a any flat shade, but by metal by default is assumed that it is made with one type of a cold rolled sheet with a particular type of carbon composition and all which we called mild steel.

So, do not be upset if it is just a sheet metal and people give you something which is just made out of cold rolled sheet, that is the common thing whenever somebody says, it is made

of sheet metal it is like the change added to that we also have generally it also comes with various types of finishes on top of it. And, why I mentioned finishes is cadmium has been found out to be dangerous a cadmium is not used anymore, but nickel is instead, nickel or in the case of if a price is lower zinc is coated like that.

All these things including the zinc plating including the what you call basic material and depending on the types of processes that are used are very critical when we specify the various types of tolerances and fits on our dimensions. So, I will stop here, I will try to come back later on. I will just stop here and go back a little and then explain this to me to you in the next lecture.

So, far I have just talked about the very very basic fits and tolerances and why it is important for us to put them into a drawing, because manufacture is not like just simply you make a drawing and somebody will you know work on it. If we do that we will again be coming back to just maybe taking an old drawing and then trying to digitize it and then let things go with that new provision we have the original model can have all the fits and tolerances built into it and when the file is transferred to the fabrication people it can be directly probably what is called a machine codes can be generated it and then they fabricated parts can be made out of it.

So, I will go back, I will come back to this later which is very big way things edge hole to the bend ok, bend to bend. What is the tolerance is there on then angular tolerances, edge to edge or hole to a hole. If you recollect seeing workshop video which was I think part of lecture seven or eight after the bending you see there is a peculiar spring back available into that.

So, they will try their best in this case ours is a folding machine at the back there is certain stops. So, you have to ensure that compensate for this spring back the part that comes out is practically usable it is not 100 percent 90 degrees, but the is tolerance of plus or minus two degrees are built inside there are some adjustments in that which ensures that the liver with it operating stops there.

So, thank you I will get back next time.

Thank you.